Processes Affecting Exchange of Mud between Tidal Channels and Flats

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LONG-TERM GOALS

The goal of our Tidal Flats research is to expand our understanding of the erosional and depositional processes that lead to exchange of mud between tidal channels and tidal flats and its impact on sediment strength.

OBJECTIVES

Our research on Tidal Flats DRI had three primary objectives:

1. Improve understanding of how turbulence and sediment concentration affect the size-dependent depositional flux of sediment to the seabed on tidal flats.
2. Improve understanding of how sediment texture and sorting in the seabed affect the size-dependent erosional flux from the seabed on tidal flats.
3. Link our understanding of erosional and depositional sorting to spatial and temporal patterns of grain size on tidal flats.

APPROACH

We have collected three types of data at the southern end of Willapa Bay, WA. We have conducted regional grain size surveys along a transect extending from the muddier southeast portion of Shoalwater Bay near Round Island to the sandier northwest portion (Figure 1). We have measured suspended particle properties with a set of instrument pods deployed simultaneously in a secondary

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14. ABSTRACT

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tidal channel and the adjacent flat (Figure 2). The instruments carried on the pods were 2 LISST-100X laser particle sizers, 2 digital floc cameras (DFCs), a digital video settling column (DVC), and a McLane in situ water transfer system. We also deployed AquaDopp acoustic current meters with each set of pods. To examine erodibility and erosional sorting, we have collected and eroded sediment cores with a Gust erosion chamber.

Hill, Law, and Milligan collaborate closely on all aspects of this project. John Newgard (Dal) and Vanessa Page and Tina Lum (BIO) provide support in the lab and field. Several undergraduate students have also provided support for the project.

We collaborate closely with several other PIs in the tidal flats group. We share cores and erosion data with Pat Wiberg (UVA). We work closely with Rob Wheatcroft (OSU) on sample collection, and we share data on sediment properties. We provide Bernie Boudreau and Bruce Johnson with cores and grain size data. We coordinate our sampling plans with Chuck Nittrouer and Andrea Ogston (UW).

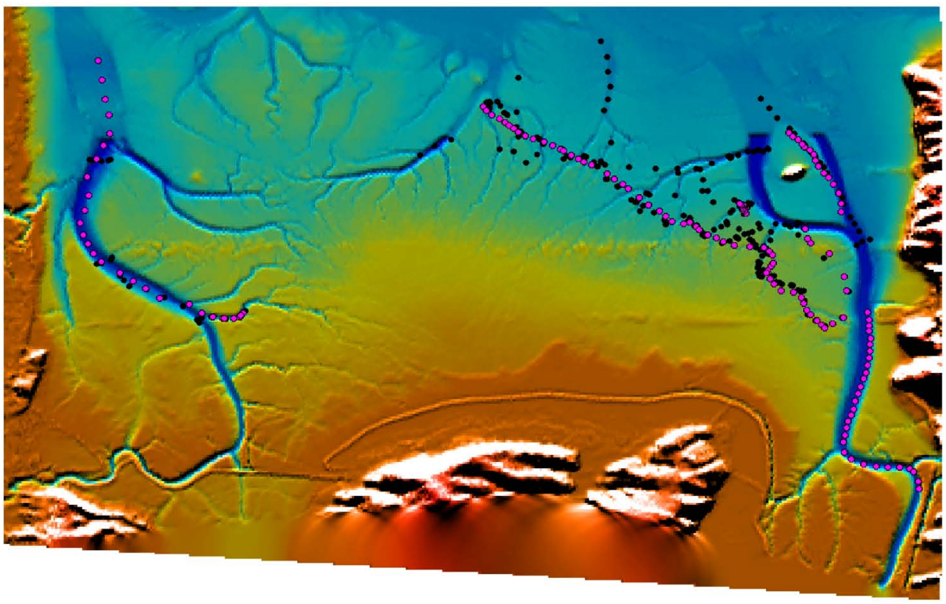

Figure 1: Sample location map for Willapa Bay Tidal Flats sediment survey. Dark symbols show analyzed grain size sample locations of surveys in September 2008 and March and July 2009 and February 2010. Pink symbols show sample locations of the most recent survey in July 2010. Color indicates flat elevation obtained from a 2002 NOAA Lidar survey. Image is ~4km wide.

WORK COMPLETED

Three major tasks were completed during the report period:

1. Analysis of July 2009 data;
2. Collection of a full set of erosion, pod, and grain-size survey data in February and March 2010;
3. Collection of another grain-size survey in July, 2010.

Figure 2. Instruments on the Willapa Bay tidal flat. From left to right, Digital Settling Velocity Camera (DVC), LISST 100x, Digital Floc Camera (DFC), and 2 Nortek Aquadopps™(on loan from Washington State University in Vancouver).

RESULTS

Several basic results have emerged from our work.

- Extent of flocculation in bottom sediment decreases as one moves from the channels to the flats (Figure 3). This trend is important because flocculation produces poorly sorted, fine sediments in the seabed, which are most likely to have low permeability, high water content and low strength.
- Maximum flow speeds on the flood and ebb tides occur as water invades and evacuates the flats. This phenomenon is well known but important because it affects suspended particle dynamics (Figure 4).
- Flood and ebb velocity pulses occur simultaneously in the channels and on the adjacent flats, resulting in the resuspension of flocs from the seabed. Flocs eroded during the flood pulse deposit at high slack water, are resuspended on the ebb pulse, and then deposit again after water leaves the flats (Figure 5). These processes make the channels and channel edges the sites of frequent floc deposition and erosion, causing low sediment strength.
- Sediment texture affects erosional sortability, as found in past work. When the clay content in the seabed grows larger than 5-10%, the mobility of all grain sizes become similar. When clay content is low, fine particles are preferentially removed at low stresses (Figure 6). This phenomenon produces a positive feedback in sediment texture. When a bed is seeded with enough fine material from floc deposition, muds tend to accumulate further.

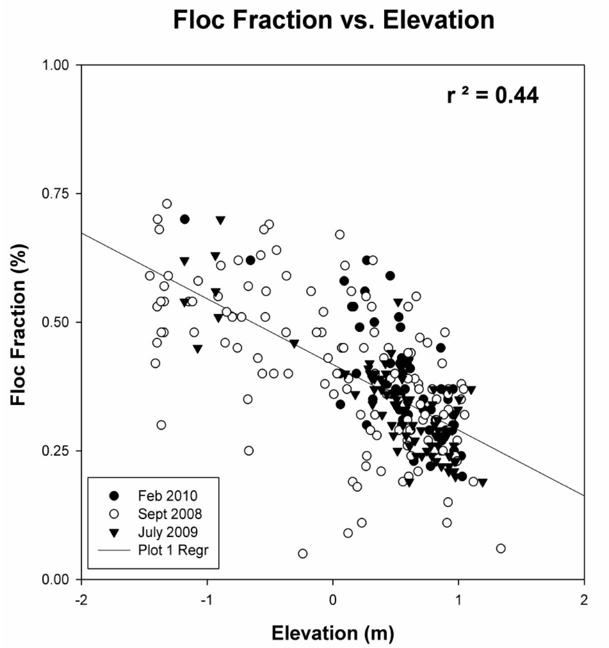

Figure 3 Scatter plot of floc fraction versus elevation on the tidal flat in Willapa Bay. Floc fraction is the fraction of sediment deposited in flocs as estimated by an inverse model of the disaggregated inorganic grain size (DIGS) distribution (cf. Curran et al., 2004) Data from 3 surveys are shown: dark circles, February 2010; dark triangles, July 2009; and open circles, September 2008. Floc fraction decreases with increasing elevation on the flats. A linear regression indicates that 44% of the variability in floc fraction is explained by elevation. Elevation data are derived from a NOAA Lidar survey of southern Willapa Bay. The Lidar datum is NAVD88 and differs from the mean water level zero datum used in Figure 4.

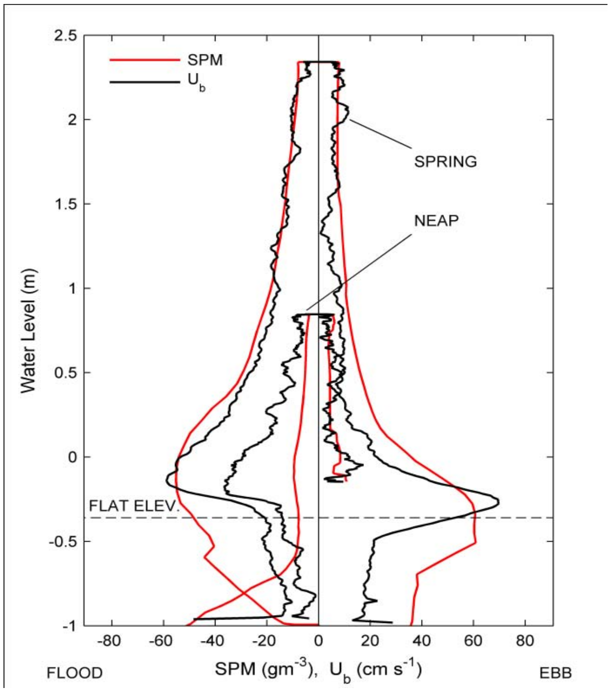

Figure 4. Plot of bottom current speed and suspended particulate mass as function of water level. Black lines show nearbed current speed as measured with AquaDopp current meters. Negative values indicate flow onto the tidal flats. Results for spring and neap tides are show. Red lines show suspended particulate mass (SPM) 0.5m above the seabed. These data were obtained by converting the beam attenuation coefficient (c_p) from the LISST-100X to SPM with c_p:SPM ratio of 0.51. The elevation of the tidal flats is indicated by the dashed line. When the water level is ~0.2 m above the flats, water surges onto the flats on the flooding tide and off of the flats on the ebbing tide, reaching speeds of over 0.6 m s-1. The flood and ebb pulses resuspend sediment. The zero datum is mean measured water level and differs from the NAVD88 datum in Figure 3.

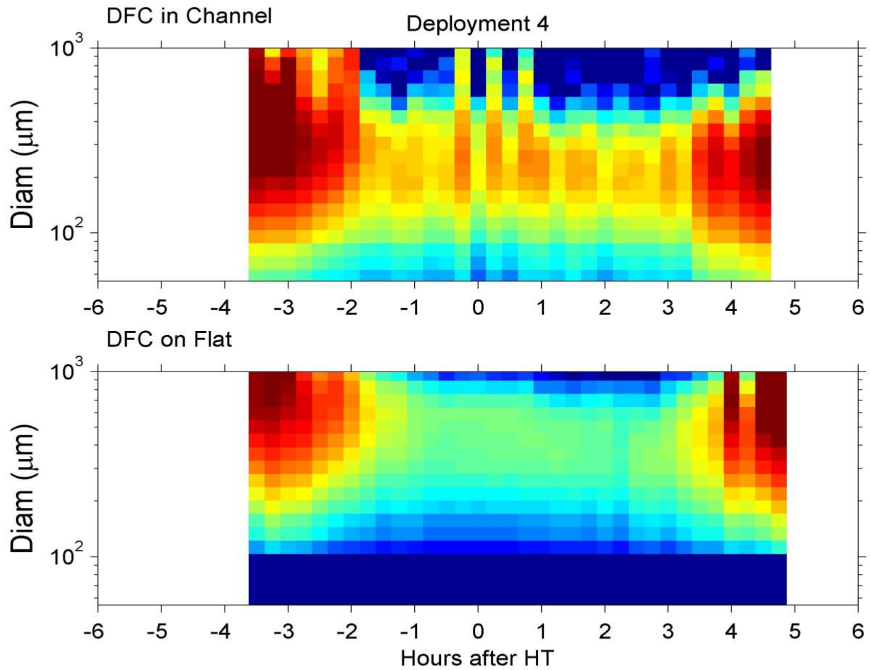

Figure 5. Volume concentration versus time in the tidal cycle as imaged by digital floc cameras in a channel and its adjacent flat. On the y axis is particle diameter and on the x axis is hours after high tide, where negative numbers indicate that observation were collected on the rising tide. Color indicates volume concentration, with red indicating high concentration. Large flocs appear in high concentration as water depths on the flats reach ~0.2 m, both on the rising and falling tides (cf. Figure 3), when current speeds are maximal. Flocs sink from suspension at high slack water. The timing of floc resuspension in the channel and on the flats is simultaneous.

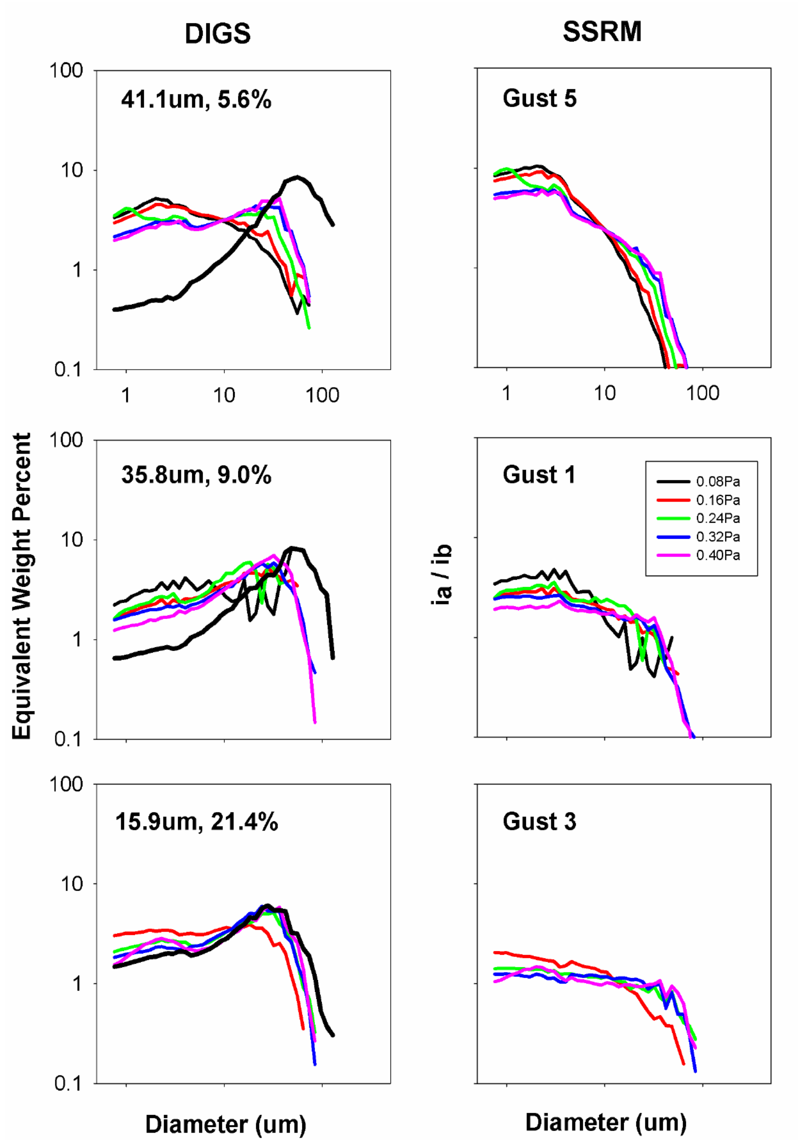

Figure 6. Results from erosional sorting studies carried out on three cores from Willapa Bay in September 2008 collected at three sites. Left panels show DIGS of bottom sediment (black) and material eroded at increasing stress (colored) with corresponding geometric mean diameter percentage of sediment < 4 μm. Right panels show, size-specific relative mobilities (SSRM) for the eroded cores. The SSRMs divide the relative concentration in a size class in suspension by its relative concentration in the bed. Values greater than one indicate preferential erosion of that size class, while a value of one indicates that the particle size has the same relative concentration in suspension as it does in the bed, i.e. there has been no size sorting. The pattern in the sand core is consistent with non-cohesive behavior, which generally occurs when the fine fraction is less than 5-10% (Law et al., 2008). The channel core shows SSRMs near to unity over a range of size classes, indicating cohesive behavior and minimal size sorting. This behavior is consistent with its large fine fraction. The GUST 1 core shows intermediate sorting behavior, consistent with its fine fraction of 9%.

IMPACT/APPLICATION

Variability in seabed properties represents a major concern for safe and efficient travel across tidal flats. Especially problematic are "oozing mudflats" (cf. Wells, 1983, Frey et al., 1989) with high porosity and low strength. People and equipment can sink deeply into such muds, making travel difficult and potentially dangerous. The link between seabed properties and "trafficability" motivates efforts to understand the formation of low-strength muds so that models that predict the locations of such deposits can be developed.

RELATED WORK

Results from the in-situ measurement of particle size, beam attenuation (c_p), and settling velocity are being applied to the ONR funded Ocean Optics OASIS project. The two LISSTs used in this project were purchased with Canadian funds, one from a project on oil-mineral aggregation (NSERC, Hill) and one on particle transport away from finfish aquaculture sites (DFO, Law).

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